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Dosimetry of Al_2O_3 optically stimulated luminescent dosimeter at high energy photons and electrons

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Abstract. The linearity of Al_2O_3 OSL dosimeters (OSLD) were evaluated for dosimetry works in clinical photons and electrons. The measurements were made at a reference depth of Z_{ref} according to IAEA TRS 398:2000 codes of practice at 6 and 10 MV photons and 6 and 9 MeV electrons. The measured dose was compared to the thermoluminescence dosimeters (TLD) and ionization chamber commonly used for dosimetry works for higher energy photons and electrons. The results showed that the measured dose in OSL dosimeters were in good agreement with the reported by the ionization chamber in both high energy photons and electrons. A reproducibility test also reported excellent consistency of readings with the OSL at similar energy levels. The overall results confirmed the suitability of OSL dosimeters for dosimetry works involving high energy photons and electrons in radiotherapy.

1. Introduction

The use of OSLD has been increasing and has recently begun replacing the thermoluminescent dosimeter (TLD) for personnel monitoring. Typical OSLDs are constructed using aluminum oxide powder doped with carbon Al_2O_3:C. The chip-shape also known as nanodot, has rendered OSLDs capable of measuring radiation doses from every direction and position. This device can be exposed and read repeatedly, with good reproducibility rate of detection. OSLD provides a wide range of energy detection with 5 kV-10 MV photons and electron energy beyond 250 keV. OSLDs also reported excellent energy dependence of 10% over a diagnostic energy range of 70-140 kVp; 5% for photon and electron from 5 - 20 MeV [1]. To date, studies concerning the characteristics of dosimetry involve the sensitivity, reproducibility and energy dependence of OSL towards low and high energy photons [2-8]. A previous study by Yahya [9] suggested that OSLDs has excellent energy dependence and dose linearity at low and high energy X-rays compared to the thermoluminescent dosimeters.

Studies on the application of OSLDs for particulate ionizing radiations such as electrons on the other hand, are limited. A readily available dosimetry protocols such as the IAEA TRS 398:2000suggested a reference depth Z_{ref} as a dosimetric parameters for electrons. The Z_{ref} was determined to be R_{80} of the electron depth dose, which is known as the therapeutic range of the electrons. The R_{80} is defined as the depth on which the target volume receives 80% of the prescribed dose. The Z_{ref} for photons, on the other hand, is measured at an approximate depth of 5 cm for 6 and 10 MV photons. This study focused on the dose measurements at Z_{ref} of high energy photons and electrons measured using the OSLDs.

2. Methodology

2.1. Preparation of Optically Stimulated Luminescent Dosimeters (OSLD) and Themoluminescent Dosimeters (TLD100)

The OSL dosimeters were annealed in a secondary standard dosimetry laboratory (SSDL) in the Malaysian Nuclear Agency (Nuclear Malaysia). Annealing was carried out by exposing the OSL to high intensity light to remove trapped charge within the OSL. The initial readings of the OSL were recorded prior to the measurement. The readings of the OSL can be calculated using the equation:

$$Dose_{OSL} = D_y - D_x \tag{1}$$

with D_x and D_y being the initial and final readings of the OSL, respectively, measured in milliSievert (mSv).

The TLD100 was selected to obtain a group of TLD chips with the lowest standard deviation values (SD) of TL signals within the group. The TLD100 chips were annealed using an annealing oven at 400°C for an hour followed by 100°C for 3 hours as per recommendations by the manufacturer [10]. Both OSL and TLD100 were calibrated at the SSDL in Nuclear Malaysia using 1 mGy of ^{137}Cs gamma energy at 1 m distance for ~1.31 minutes.

2.2. Dose Measurements in High Energy Photons and Electrons

The absorbed dose at Z_{ref} was measured at 6 and 10 MV photons, and 6 and 9 MeV electrons using Varian Clinax IX as the source of the photons and electrons. Solid water phantoms were used as a medium and the OSLDs and TLD100 were placed at the Z_{ref}, as shown in figure 1. The Z_{ref} for photons were measured at a depth of 5 cm for 6 and 10 MV photons while the Z_{ref} for electrons were measured at depths of 1.34 and 2.06 cm for 6 and 9 MeV electrons, respectively, based on previous calibration measurements. Bolus was added onto the solid water phantoms to provide depth and minimize air gaps created while positioning the OSLDs and TLD100. The OSLDs and TLD100 were exposed to photons and electrons at 100 cm source to surface distance (SSD), 10 cm x 10 cm field size on the surface and 100 monitor unit (MU) based on the calibration condition recommended by IAEA TRS 398:2000.

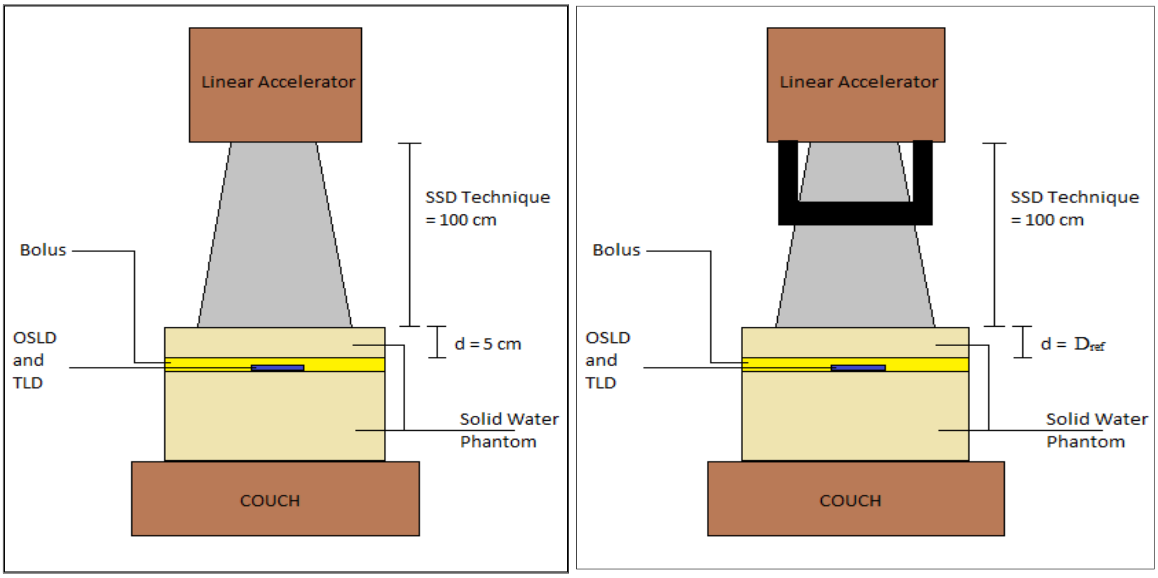

Figure 1. The experimental set up for dose measurement at (a) photons and (b) electrons.

The doses by OSLDs were measured using a portable OSL reader type MicroStar. The OSL dosimeter was analyzed using a stimulated element aluminum oxide, (Al_2O_3) at a wavelength of 532 nm (green light). Radiation charges from X-ray or high energy photon of Themoluminescent dosimeter (TLD-100) was read by the TLD reader model Harshaw 4500 using a WinREMS software. The measurement error, σ for both OSLDs and TLD100 was determined using equation 2:

$$\text{Error}, \sigma = \frac{\text{dose}_{\text{max}} - \text{dose}_{\text{min}}}{2} \quad (2)$$

The absorbed dose by OSLDs and TLD100 was compared to the value by ionization chamber, acting as a standard dosimeter for calibration purposes. The chi-square χ^2 calculation was used to determine the closeness readings by OSLDs and TLD100 to ionization chamber, as per equation 3:

$$\chi^2 = \left(\frac{D_{\text{std}} - D_{\text{exp}}}{\sigma}\right)^2 \quad (3)$$

with D_{std} and D_{exp} being the dose measured using ionization chamber and OSLDs/TLD100, respectively, and σ is the measurement error of the dosimeter measured using equation 2.

3. Results and Discussions

The measured absorbed dose at Z_{ref} for 6 and 10 MV photons compared to the readings of the ionization chamber is tabulated in Table 1. The results showed that the absorbed dose by OSLDs was closer to the value reported by the ionization chamber in the case of both 6 and 10 MV photons. The absorbed dose by TLD100, on the other han,d was significantly lower than that of the ionization chamber and OSLDs. The results were in good agreement to the study of absorbed dose by OSLDs, at a depth of maximum dose d_{max} at high energy photons, reported by Yahya [9]. The reproducibility of OSLDs, and TLD100 were better when the measurements were done at lower energy photons, as confirmed by the lower σ values. The reproducibility at higher energy photons was significantly higher for both OSLDs and TLD100, which is consistent with Yahya [9].

Table 1. The detailed value of absorbed dose by OSLDs and TLD100 compared to the ionization chamber for 6 and 10 MV photons

Energy (MV)	**Absorbed dose (cGy)**				
	Ionization chamber	**OSLD**	σ_{OSLD}	**TLD100**	σ_{TLD}
6 MV	874.54	815.41	4.93	481.07	3.10
10 MV	937.76	874.61	10.69	473.07	15.96

The absorbed dose at Z_{ref} in 6 and 9 MeV electrons measured using OSLDs and TLD100 compared to the ionization chamber is shown in Table 2. The results showed that the readings by the OSLDs were closer to that of the ionization chamber at 6 and 9 MeV electrons compared to the TLD100. The readings by TLD100 were significantly lower than that of the ionization chamber and OSLDs, similar to the results obtained in the photons measured earlier. The OSLDs reported better reproducibility compared to TLD100 at both 6 and 9 MeV electrons, as evidenced by its lower σ values.

Table 2. The detailed value of absorbed dose by OSLDs and TLD100 in comparison to ionization chamber for 6 and 9 MeV electrons

Energy (MV)	**Absorbed dose (cGy)**				
	Ionization chamber	**OSLD**	σ_{OSL}	**TLD100**	σ_{TLD}
6 MeV	997.998	892.12	1.33	522.309	21.18
9 MeV	1012.725	866.22	11.69	548.179	42.23

The χ^2 values of OSLDs and TLD100 to ionization chamber at both photons and electrons is shown in Table 3. The results showed that the dosimetry readings by OSLDs were closer to the value ionization chamber at all measured photons and electrons compared to that of the TLD100 as per its lower χ^2 values. The results are consistence with a previous study comparing OSLDs and TLD100 signal towards ionizing radiations by Yahya [9]. The overall results confirmed the suitability of

OSLDs as a dosimeter for quality assurance and dosimetry works involving high energy photons and electrons.

Table 3. The χ^2 values of OSLDs and TLD100 to ionization chamber for 6 and 10 MV photons and 6 and 9 MeV electrons

Energy	OSLD	TLD100
6 MV	2.068×10^4	1.611×10^6
10 MV	34.54	8.472×10^2
6 MeV	25.99	5.044×10^2
9 MeV	20.84	1.210×10^2

4. Conclusions

Dose measurement using OSLDs were almost similar to that of reported by the ionization chamber compared to TLD100H at all high energy photons and electrons. The OSLDs also reported good reproducibility of readings as per by the low value measurement errors. The dose measured using TLD100 was significantly lower than that reported by the ionization chamber and OSLDs. The results confirmed the suitability of OSLDs as a dosimeter for high energy photons and electrons.

5. References

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